Snohomish County Surface Water Management
Resource Monitoring Group

Standard Operating Procedures for Wadeable Stream Habitat Surveys for Status and Trends Monitoring

Samples Version 1.0

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Please note that Snohomish County Surface Water Management's (SWM) Standard Operating Procedures (SOPs) are adapted from Washington State Department of Ecology Standard Operating Procedure EAP 109 version 1.6, other published methods, or developed by in-house technical and administrative experts. Their primary purpose is for internal Snohomish County use, although sampling and administrative SOPs may have a wider utility. Our SOPs do not supplant official published methods. Distribution of these SOPs does not constitute an endorsement of a particular procedure or method.

Any reference to specific equipment, manufacturer, or supplies is for descriptive purposes only and does not constitute an endorsement of a particular product or service by the author or by Snohomish County.

Although SWM follows the SOP in most cases, there may be instances in which the County uses an alternative methodology, procedure, or process.

SOP Revision History

Revision Date	Rev number	Summary of changes	Sections	Reviser(s)

Standard Operating Procedures for Wadeable Stream Habitat Surveys for Status and Trends Monitoring

Introduction

Snohomish County Surface Water Management (SWM) implements the "State of Our Waters" monitoring program in stream, river, lake, and estuary environments. SWM conducts the State of Our Waters program in streams and rivers with the goal of documenting the current status and changing trends in salmonid habitat quality and quantity. This report documents the standard operating procedures for conducting stream habitat monitoring in wadeable streams, which are defined to be less than 30 meters in bankfull width. Previously, stream habitat monitoring conducted by SWM directly supported salmon recovery planning by documenting stream condition status and comparing these results to regional performance standards for habitat quality (e.g., NOAA 1996, Spence et al. 1996; WFPB 1997; SRBSRTC 2002). These assessments informed the development of habitat protection and restoration strategies and projects. Now, the State of Our Waters program focuses on the status of conditions (quality and quantity) and on trend detection to assess changes in conditions that can be interpreted with respect to salmon habitat and stream health; specifically, "Are habitat conditions in Snohomish County rivers and streams improving to meet salmon recovery habitat goals and objectives that contribute to Puget Sound watershed recovery goals and targets?"

Wadeable streams comprise the largest proportion of drainage networks and are considered shallow enough to safely survey during summer low flow periods without the use of a boat, approximately up to 30 meters wide as stated. Aquatic habitats and riparian areas reflect upstream and upland watershed processes that govern the supply, transport and storage of water, sediment, and organic material. The distribution, composition, abundance, frequency and rate of change of habitats may be influenced by important controlling factors such as land cover, geology, basin geomorphology, channel network dynamics, climate and watershed disturbance history. Conceptually, the links in these relationships are shown in the State of Our Waters Quality Assurance Monitoring Plan (QAMP – Figure A-3) As such, for each monitoring site, relevant upland and channel geomorphological attributes will be calculated. The relationship among these landscape controlling factors (independent variables) and habitat factors (dependent variables) suggests that multi-parameter linear or non-linear models can be used to interpret the effect or influence of independent variables on dependent variables. As part of future reporting, habitat monitoring results generated using this protocol will be used to parameterize and validate alternative watershed models that will help answer monitoring and management questions.

Beginning in 2000, Snohomish County identified a limited set of habitat parameters relevant to salmonid habitat limiting factors (e.g.; NMFS 1996) that were diagnostic of condition, suitability and needs. Then and now, we employ a relatively rapid assessment that relies on continuous and regular transect-based quantitative measurement to maximize precision and repeatability. This effort to assess stream habitat conditions and health is also now companion to watershed evaluation, water quality monitoring, benthic macroinvertebrate sampling, and flow monitoring (see the QAMP). The survey parameters included in this monitoring protocol and their descriptions are included in Table 1.

Table 1. Wadeable stream survey parameters, source of data collection (T-transects and number; C-continuous), and descriptions.

Survey Parameter	Source	Description
Channel Conditions - Bankfull Width (BFW) and **Depth (BFD)** –measured to nearest 1 cm	T - 11	Bankfull Width measures the channel size most often influenced by channel forming flow (approximately 2-year recurrence interval) delivered from the watershed upstream. It is the primary measure used to determine channel size and minimum size of functioning pools along a reach. BFW is used to normalize summarized data among BFW categories. The width/depth ratio is a metric used to characterize channel shape as flow varies).
Stream Bank Conditions	C	Inventory of the length of bank modifications (human-made), such as placed rip-rap and assessment of bank erosion within a surveyed stream or river segment. Measured to nearest 10 cm.
Riparian Condition - Canopy Cover and **Disturbance**	T - 11	Vegetative cover that provides shade, stabilization of soils, and contribution of organic matter to the stream measured with densiometer. Measurements made in 4 directions at center of channel and at stream bank facing bank. At streambanks, assess presence of dominant human disturbance, bank angle, bank cover, and invasive vegetation within five meter plot along bank and upland at transect.
Instream Wood Pieces – also known as Large Woody Debris (LWD) count and frequency by survey length	C	Measurement of characteristics and quantity of instream wood. Instream wood provides habitat complexity, cover, and hydraulic roughness. All wood larger than two meters length and 10 cm diameter is counted. Wood characteristics include wood length class, diameter class, wood type (conifer/deciduous), decay class (young, med, old). Values establish a baseline LWD size and density for the reach for future comparison and to assess LWD enhancement needs in certain cases.
Instream Wood Jams – count and frequency by survey length	C	Measurement of wood jams include jam type based on position within the channel, visually averaged jam length, jam width, and jam height. All wood larger than two meters length and 10 cm diameter is counted.
Habitat Units (riffle/glide/pool) – area to 0.01 m^2; maximum depth to nearest 1 cm.	C	Measurement of total habitat area (total length and visually averaged width) by unit and type and percent composition among types. For pools, pool tailout depth is measured to calculate residual pool depth and the pool forming factor creating the maximum scour depth is identified as one of: Riprap ▪ Bedrock ▪ Wood ▪ Beaver (dammed or plunge pool) ▪ Free Form (lateral or converging scour) ▪ Boulder
Side-Channels	C	Quantification of side channel length, width, habitat composition and area.
Substrate Size– measured at B-axis to nearest 1 mm.	T - 11	Size distribution of surface substrate particles in a stream reach using pebble count technique – 10 pebbles per transect; serves as important living space in each habitat type (e.g., silt, sand, small gravel, large gravel, small cobble). Note that surface substrate is also measured from benthic macro invertebrate sample riffles by the survey team, which is detailed in a separate SOP.
Channel Conditions - Gradient	T - 3	Measurement of water surface elevation differences between transects establishes the reach gradient using the average slope among 3 transect pairs. Results are used to bin streams by gradient category and interpret habitat results. Data used to ground-truth the LiDAR-derived stream gradients for evaluation of remote-sensing.

The extent of the stream survey sites (the sample frame) is described in the body of the State of Our Waters QAMP. To achieve strong inference, we use a random sampling approach to extrapolate our results to all streams or categories of assessment. In this way we can broadly answer whether habitat conditions for fish are functioning, impaired or degraded across a proportion of the sample frame and assess the variability in condition by several factors, including land use. It also allows for the detection of trends in habitat conditions over time based on the changing distribution of results within the context of precision error and repeatability.

Although the benefits of random sampling are well known, targeted sampling of wadeable stream sites established 6-14 years ago around Snohomish County also represents an additional opportunity to detect early trends for some indicators based on repeat site monitoring, as many of these more than 300 stream sites will overlap with new randomly selected sites. Both approaches allow comparisons of aggregate monitoring results over time to Salmon Recovery Plan-specific habitat targets and unique site-specific changes where older data were collected. In our sampling scheme, we have made an effort to balance the tradeoffs of each approach and fulfill the information needs of Snohomish County and watershed partners. Important management and monitoring questions are included in Section 6.0.

1.0 Purpose and Scope

1.1 This Standard Operating Procedure (SOP) details methods used by Snohomish County Surface Water Management Resource Monitoring group (RM) to conduct physical habitat surveys in wadeable streams. Collection of this habitat data uses two approaches for these characterizations: 1) transect-based methods, and 2) point-based methods for continuous data collection. Several types of habitat data are collected and include the following elements for transect and continuous data collection categories. Both types of physical habitat measurements will be described in Section 7.0.

Transects
- Channel measurements
- Substrate size
- Riparian condition

Continuous
- Habitat units
- Large Woody Debris (LWD)
- Bank conditions
- Substrate size for Benthic Macro Invertebrate sample riffles (described elsewhere)

1.2 The scope of this SOP applies to sampling equipment acquisition and preparation including confirmation of proper function and battery charge of all electronic measuring and data storage devices. Each new field staff member must be trained by a custodian or other designated proficient user of the measuring equipment and data storage devices. Habitat characterization requires advanced training in order to understand how to collect data and requires that senior scientists provide the training and mentorship.

1.3 Operating instructions for equipment should be consulted for detailed information. Failure to do so, could result in collection of unusable physical habitat data. Both written instruction and designated scientists should be consulted to ensure data is collected uniformly.

2.0 Applicability

This SOP is intended for any SWM program involving the collection and analysis of physical habitat data collected from river and stream reaches selected as part of the State of Our Waters monitoring program. In addition, this protocol is applicable to stream sites where restoration projects have been implemented in order to describe pre-project baseline conditions and post-project outcomes. Other protocols and measurements may also be desired for that type of project effectiveness monitoring.

3.0 Definitions

Definitions primarily are associated with the descriptions of the individual monitoring measurements and what field indicators or condition requirements those are based on to assure consistent implementation of the protocols by staff. The definitions supporting the identification of the individual monitoring measurements also are based on regional coherence of habitat descriptions intended to distinguish the suitability of the habitat condition. Definitions are provided in Section 7.0.

4.0 Personnel Qualifications/Responsibilities

4.1 This SOP pertains to all SWM RM staff. Field operations require training specified by job title in SWM's Safety Training database. All field staff must have read the instrument manuals, this SOP, completed field training and be familiar with procedures for data collection. All field staff must be familiar with the electronic data recording tablet (ESRI Arc GIS Collector application).

4.2 The field lead directing sample collection must be knowledgeable of all aspects of the project's Quality Assurance Monitoring Plan (QAMP) to ensure that credible and useable data are collected. All field staff should be briefed by the field lead or project manager about the sampling goals and objectives prior to arriving at the site.

4.6 To minimize observer/method variability and bias, training is conducted at the beginning of each survey season. Training is organized to demonstrate survey method techniques and equipment used. Measurements common to bias, errors, and high variability are identified in past repeatability analysis (Snohomish County 2002, and ongoing repeat surveys) allowing for additional emphasis on method training. The protocol is reviewed and practiced to ensure methods are understood and team members are able to demonstrate correct measurements. Training surveys are repeated and survey data is compared to identify potential high variability.

5.0 Equipment, Reagents, and Supplies

Apple iPad®	ESRI Collector for ArcGIS (V18.0.2)
Trimble GeoExplorer (XT/XH)	Stadia Rod (metric)
Laser Range Finder	Hip Chain (metric)
Convex Spherical Densiometer	Vernier Caliper or Metric Ruler
Hand Level - Pea Gun	Rite in Rain field handbook
Flagging Tape/Indelible Pen	Monopod - fixed length (for hand level)
Manual Tally Counter	Reel tape (10 meter)

6.0 Study Summary

Important management and monitoring questions relevant to stream channel characteristics and selected habitat conditions are included in Table 2. Based on the analysis of all sites and conditions represented by them, the likely mechanism(s) operating to limit conditions or cause impairment (or improvement) in habitats will be investigated as will relationships between survey parameters. Descriptive and predictive models can be developed and validated in new sampling areas and can be used to hypothesize likely future habitat changes. If successful, this approach to monitoring and assessment will strongly support adaptive management decision-making. However, the objectives of this report are to describe sampling protocols for physical habitat inventory in wadeable streams and summarize key aspects of data collection, file storage and database management at Snohomish County. Exploration of the monitoring questions will be reported elsewhere.

6.1 Study Goals

In addition to long-term trend detection, the monitoring strategy is designed to provide useful and relevant information to inform conservation and restoration decision-making and adaptive management pertaining to the following questions;

1. How does land use/land cover affect in-stream physical habitat conditions in Snohomish County?
2. What fraction of existing habitat conditions compare favorably or unfavorably to habitat performance standards and local targets?
3. Where are good and poor habitats located and how are their abundance and distribution changing over time?
4. What and where are restoration and protection efforts needed (i.e., location or amount)?
5. Are changes to the survey methodology developed for status and trend monitoring needed to better inform adaptive management decision-making?

Snohomish County's wadeable stream monitoring approach integrates effects of potential impacts and enhancement (from restoration actions) at multiple scales (on-site and upstream). As such, the methods may help to distinguish and evaluate the cumulative effectiveness of recovery actions.

Table 2. Monitoring indicators and associated management and monitoring questions. Not all questions are addressed in this report.

Monitoring Indicator	Relevance	Question	Indicator Metrics
Instream Wood (LWD - includes small and large fractions >2.0 m length, >0.1 m diameter and description of woody debris jams)	Status	-What are the characteristics and functions of LWD? What condition based on performance criteria represents the baseline?	LWD frequency, loading, volume
		-What are the characteristics and functions of LWD jams? How much LWD is in jams?	Jam frequency, size, proportion of LWD
	Interactions	-Is large woody debris forming pools more frequently where LWD is abundant? Is LWD loading or frequency correlated with pool habitat quantity or quality?	Percent pools formed by LWD, correlation coeff.
		-How does Jam count/frequency vary with total LWD, land use or channel size?	Jam number, frequency
		-How does LWD abundance vary with amount of streambank armoring?	LWD frequency
		-Is LWD abundance correlated with watershed or riparian land cover condition?	LWD loading or volume
	Trends	-Is abundance and proportion of LWD in the low flow channel increasing?	LWD pool form factor
		-Is large woody debris of different size fractions increasing in abundance?	LWD size fractions
		-Are LWD jams becoming more abundant and frequently spaced?	LWD jam frequency
Habitat Units - (pools, riffles, glides, side channels)	Status	-What are the characteristics and functions of pools based on performance criteria? What is the composition of riffles and glide habitats?	Pool, riffle, glide frequency/area
		-What forms most pools and what quality characteristics are present?	Pool form factor, pool spacing, pool depth
		-What are the distinguishing differences between Primary and Backwater pools?	Pool area, depth, form factor
		-What is the total and % length and area of side channels	Side channel frequency, length, area
	Interactions	-What relationships exist between LWD and pools? Between bank conditions and pools? Between land cover and pools?	Regression function; factorial analysis
		-Is the abundance of side channel habitat correlated with bank modifications or LWD abundance? Is side channel presence explained by stream slope only?	Regression function; factorial analysis
		-Are primary or backwater pools more typically correlated with LWD abundance or spacing?	Regression function; factorial analysis
	Trends	-Is pool frequency, area, and residual depth increasing?	Slope is not = 0 or >0
		-Are there more LWD formed pools? Does this decrease pool-pool spacing?	Slope is not = 0 or >0
		-Is mainstem riffle frequency/area increasing or decreasing?	Slope is not = 0 or >0
		-As habitat improves, is unit habitat composition shifting away from glide habitat?	Slope is not = 0 or >0

Monitoring Indicator	Relevance	Question	Indicator Metrics
		-Is relative proportion and frequency of all habitat types (pools, riffles, glides, and side channels) more diverse?	Relative standard deviation is increasing
Riparian Condition - Canopy Cover at bank and mid-channel stream site cover and **Disturbance**. (Land cover analysis within riparian buffered area is covered elsewhere.)	Status	-What percentage of the riparian buffer is providing adequate cover for shading?	Percent canopy cover
	Interactions	-What spatial scales (i.e., reach, upstream riparian buffer, land use) are good predictors of LWD recruitment and jam formation?	Percent cumulative upstream riparian buffer > 150 ft. wide
		-Are there sub-basins with high development but that still have an intact riparian buffer?	Vegetative cover classification, composition, and other vegetation metrics from low- and high-resolution satellite imagery (i.e., Landsat and Quickbird, respectively)
	Trends	-Is composition of natural land cover increasing in riparian and floodplain areas?	
		-Is composition of impervious area in buffers decreasing?	
		-is composition, extent, and connectivity of mature vegetation increasing?	
		-Is number of breaks (road crossings, utilities, clearing) decreasing?	
		-Is canopy cover increasing?	
Channel Condition – (Including side-channels)	Status	-What do existing channel conditions indicate about watershed condition?	Channel type, width:depth ratio
	Trends	-Is cross-channel width, depth or area increasing or decreasing?	BFW, BFD, Gradient, Percent channel composition
		-Are channels aggrading or incising?	
		-Are side channels increasing in number, length or area?	
Substrate Size –	Status	- What is the proportion of fines and sand among sites and what is the level of impairment?	Percent < 2 mm
	Trends	- Are average sediment particle sizes increasing? Is the proportion of fines and sands increasing or decreasing?	Cumulative distribution; Slope is not = 0 or >0
Stream Bank Condition – modification, stability and cover	Status	-What is the degree of modification and stability of streambanks?	Percent composition of modifications and stability by reach;
		-Are the amounts of armoring and instability related within survey sites?	
	Interaction	-Do bank modifications limit LWD storage, enhance LWD transport, limit LWD recruitment and reduce or eliminate vegetation resulting in lower stream LWD loading or frequency?	Regression functions;
		-Is LWD, canopy cover, pool habitats or substrate size correlated with modified or unstable streambanks?	
		-Do modified or unstable streambanks correlate with poor LWD pool quality or quantity?	
		Do areas with more bank modification have less bank cover for fish?	
	Trends	Are bank modifications (armoring) increasing or decreasing?	Cumulative distribution

6.2 Study Design

To answer study goals 1-4, a rotating basin / panel design is employed, where the Stillaguamish, Snohomish and Lake Washington Basins are combined as a single area where 30-35 sites are randomly selected each year. Twenty of these sites are identified as trend sites and visited each year. The remaining sites are new sites added to the total sampled during succeeding years. For each location the predominant land use is characterized by both local zoning and urban growth affiliation but also from the composition of land cover upstream from each site (the catchment). Land cover data are discussed further below.

It is anticipated that analysis of datasets to determine the status of stream health will be conducted each year and trends in stream health will require a minimum of three years sampling. Sampling under the current design began in 2018 and will continue in order to describe trends within each of the land use settings and status of stream condition.

6.3 Random Site Selection

A reach selection process identified wadeable stream segments that would best meet the goals of Snohomish County integrated monitoring. First, a geographic sample frame was identified based on areas of inclusion or exclusion in WRIAs 5, 7, and 8. Next, the Washington State Master Sample (From Department of Ecology) of randomly generated, spatially balanced stream sample sites was added to the sample frame. The Washington State Master Sample of sites was generated using a Generalized Random Tessellation Stratified (GRTS) technique to select sites that are spatially balanced by stream order which are then randomly assigned a site identification number for a sample draw. Ostensibly, each GRTS point is affiliated with a one kilometer stream segment in the National Hydrography Dataset (NHD) so sampling can occur within that length.

Snohomish County then classified these stream points within the sample frame based on land use affiliation – current and future land use. Some best professional judgment was used to “correct” some sites that were contained within the margin of one land use, but were predominantly affected by the adjacent and different upland land use. The balance of sites contained in each major land use type (Urban, Rural, Forested, and Agriculture) was determined based on anticipated variance among land uses. Annually, up to fifty sites are drawn from the sample frame based on this balance of site type. More information is available in the QAMP.

6.5 Site Reconnaissance

Each potential sampling site identified through the GIS site selection process is evaluated prior to sampling for verification that target conditions for sampling are present. This generally can be accomplished based on available air photos and some prior knowledge by field staff of stream conditions. The following criteria must be met for sites that can be sampled:

- Access, preferably via a road right-of-way - make sure you have notified landowners in vicinity of sampling and gained permission if necessary to cross over private property to gain access,
- Riffles present – in absence of well-defined riffles, choose the fastest flowing, most turbulent, non-depositional location possible),
- Pebbly, gravely, or rocky substrate,

- Minimum channel width of one foot,
- Water depth ranging from one inch to one foot.

Sites without suitable flow, depth, width or substrate are eliminated. If the site is visited for reconnaissance purposes, a photograph is taken to document viability or non-viability. As feasible the channel width is also measured or estimated. Photos are stored in the appropriate years' folder at:

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Photos are used as reference for viable and non-viable sample locations and will be referred to in future years should the site be randomly selected once again.

6.4 Property Access

Once fifty sites are drawn from the sample frame that meet site evaluation criteria, this list is submitted to the Snohomish County Public Works Department, Engineering Services' Right-of-Way Group for verification of ownership. If privately held, permission is requested using an official Snohomish County "right-of-entry" form to access the site for current and future monitoring visits. Once final selections are made for sites that are accessible for sampling, they were recorded using geospatial coordinates to delimit the survey reach, particularly if some land owners deny access.

When sites are accessible from the County road rights-of-way, landowners are notified that the County will be accessing the streams via the County road right of way for purposes of sampling stream bugs and other media. When a site requires access through a private parcel, landowners are asked for permission by the Public Works Department Engineering Services Right of Way Group to walk through their property to the site. If access is denied to many locations, new GRTS locations may need to be drawn, and the process starts over.

7.0 Survey Procedure

7.1 Survey Delineation in a GIS

The purpose of this process is to develop equally spaced transects upstream and downstream from GRTS points to be used for in-field stream surveys. Transects were generated via script (Python) based on stream bank full width values assigned to each survey site using known information, reconnaissance measurements, nearby/similar sites, of LiDAR imagery. The digital elevation model was prepared from LiDAR point clouds collected primarily in 2015, with some small areas collected in 2014. It has a three foot resolution. No smoothing was performed prior to its use in this process.

In order to take advantage of the tracing capabilities of the NHD flowlines, the geometries had to be corrected for a number of streams. Where applicable, the NHD flowlines were adjusted to either Snohomish County's mapped watercourses or to the observable channel in the best available digital elevation model.

Stream transects were produced using the GRTS point as the center point, from which 11 transects would extend out upstream and downstream. Some GRTS points needed to be re-positioned to the NHD flow lines. Transect spacing was based on the average bank full width of the particular stream, with larger bank full widths producing farther spaced transects. Table 3 depicts the relationship between bankfull widths and transect spacing.

Note that if the bankfull width dimension as estimated is close to the upper bound of a range (e.g., 5.0-9.9 meters), the selected transect interval should conservatively be based on the next larger interval (i.e., 10.0-14.9 m, in this example). To produce the transects, the tool splits the customized stream segment (realigned NHD) for each IM site at the location of the IM site. It then uses linear referencing to place points at the correct transect spacing along each upstream and downstream segment. It then inserts offset points to the right and left of each transect point, offset to half of the average bank full width plus 10 ft. It uses a point to line conversion tool to connect the offset points to create a transect line, then properly attributes the line.

The creation of upstream and downstream transects (more than needed for the survey) allows for some flexibility when choosing the Transect 1 or start point, depending on access, permissions and other site conditions or constraints, though generally is selected closest to the actual GRTS point if feasible. In the field, the survey team navigates to Transect 1 using the tablet computer and ESRI Collector for ArcGIS. The spatial position of Transect 1 (which is recorded in the field) may then be used later delineate the upstream catchment boundaries for generating GIS-based descriptions of the contributing area and watershed characteristics, including land cover.

Table 3. Wadeable survey reach lengths by bankfull width range and transect spacing for the target 11 transects.

Bank Full Width (m)	Reach Length (m)	Transects and spacing										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
0 - 2.4	50	0	5	10	15	20	25	30	35	40	45	50
2.5 - 4.9	100	0	10	20	30	40	50	60	70	80	90	100
5.0 - 9.9	200	0	20	40	60	80	100	120	140	160	180	200
10.0 - 14.9	300	0	30	60	90	120	150	180	210	240	270	300
15.0 - 19.9	400	0	40	80	120	160	200	240	280	320	360	400
20 - 30	600	0	60	120	180	240	300	360	420	480	540	600
>**30**	800	0	80	160	240	320	400	480	560	640	720	800

7.2 Survey Strategy

Survey teams generally consist of two to four surveyors. The lead surveyor is responsible for data entry into the field computer and survey coordination. It is important for the survey lead to coordinate the survey so that measurements are not overlooked and surveyors are proceeding at a pace consistent with data entry.

At the start of each survey, field staff navigate to Transect 1, and from the middle of the stream channel collect the spatial positioning coordinates for the location using the “reach info” feature. Table 1 includes the survey parameters and Appendix A includes the fields for data entry.

Parameter definitions, data collection methods, data numbering/recording, and specific instruction follows.

Teams begin each reach by collecting data at Transect 1, including measuring bankfull width, wetted width, bankfull depth, substrate size across the gravel-bedded channel, canopy cover at the center of the channel and facing the streambanks, and estimates of riparian condition. After these data are collected and input to the table computer then continuously distributed survey parameters are collected for other features. Every feature is recorded with spatial information (GPS coordinates) so the actual position of the data entry should be at the downstream end of the feature.

In an upstream direction, surveyors collect continuous physical habitat and transect data as described below and tie flagging at locations of transects in order (#1-11) for stream gradient measurements between two sequential flags. When the final transect (i.e., the survey end point) falls within a qualifying habitat feature, surveyors measure and record the information for that feature only up to the final transect. In the case of a pool, however, maximum depth is measured even if it is upstream of the final transect. In the case of a piece of upstream LWD, it is counted if any fraction crosses the final transect.

After completing the upstream continuous survey, surveyors measure the gradients between flagged transects and collect log jam and side channel data in a downstream direction. Teams retrieve all flagging, except the flag that marks transect 1 if the reach has been selected for a future within-season repeat survey (to estimate measurement error).

7.3 Protocol for Dry or Intermittent Main Channels

Channels that are dry at the time of the survey are surveyed for bankfull width and depth, wood, bank condition, and transect metrics. In perennially flowing streams, side channels may be dry. If these channels have standing water in pools that meet the survey criteria, the pools are recorded. In streams with intermittent flow (some surface/ some sub-surface flow), stream units with no surface flow are entered as riffles. Record the locations of the inlet and outlet of the side channel and the length of each unit of dry channel. For dry channel locations, record a wetted width of zero. This ensures total length, including the spatial location of the inlet and outlets of side channels, is recorded and preserved and that habitat area is only estimated based on wetted units.

7.4 Transect Characterization

The spacing of transects is determined in advance from the estimate or, in some cases, the known bankfull width of the stream near that location. As mentioned, the field team navigates to the first transect, which is either closest to the random GRTS point or is shifted downstream or upstream to match the landowner permissions and “right-of-entry.” Beginning at transect 1, data are collected from 11 equally-spaced transects as survey teams move upstream. A GPS location is recorded at each transect (thalweg) and transect information is recorded in the ESRI Collector for ArcGIS attribute table for each element of the transect feature class. Required values for data input are specified below. At each transect, the dominant feature (pool, riffle, other) across a majority of the stream width is identified, measured and recorded. Teams collect data on wetted width, bankfull width, bankfull depth, stream cover (shading), substrate size, and riparian disturbance and near stream characteristics as described below. The transect location is flagged in order to measure stream gradients between flagging tape.

Bankfull Width (BFW) and Depth (BFD)

Purpose: Bankfull width is the primary measure of channel size and is used to determine the minimum size of functioning pools along the reach, as well as the unit reach length. Bankfull depth is also measured to calculate a width to depth ratio and judge floodplain connectivity and channel entrenchment.

Definition: Bankfull width is the width of a stream channel at the point where over-bank flow begins during a 1.5-2 year flood event. Straight, low-gradient riffles with uniform banks, few or no obstructions (such as jams), and no side-channels are the best locations for measuring bankfull width. Bankfull width is located using any of the following indicators: the top of deposited bedload (gravel bars), stain lines, the lower limit of perennial vegetation, moss or lichen, a change in slope or particle size on the stream bank, and undercut banks (USFS 1999). Bankfull depth is defined as the vertical distance between bankfull stage and the thalweg depth (Rosgen 1996). For the purposes of this survey, BFW and BFD are measured at each transect, regardless of the habitat type. This ensures that the average bankfull width is representative of the reach overall and incorporates the variability present.

Procedure: The BFW attribute is selected in the Transect feature class for data entry. Using a laser rangefinder or stadia rod, bankfull width and wetted width is measured as the horizontal distance at each transect to the nearest 0.1 meter. Bankfull depth is measured by one surveyor at bankfull stage using a hand level (pea gun) and another surveyor holding a stadia rod vertically in the thalweg location along the transect. The known height of the hand level rod (monopod) is subtracted from the reading on the stadia rod to calculate the BFD height to the nearest 0.1 meter. As feasible the lower elevation (stage) stream bank is used for this measurement. Alternatively over vertical measurements can be combined to measure the bankfull depth. The maximum water depth measured in the thalweg can be added to the bank height above the water surface at a separate transect location provided the water surface is flat across the transect (usually true).

Required Values for data entry: Transect number (1-11), Bankfull width (0.1 m), Wetted width (0.1 m), and Bankfull depth (0.01 m).

Stream Cover

Purpose: To assess vegetative cover at the transect indicating the amount of shade provided for stream cooling or cover on streambanks as well as potential inputs of organic matter.

Procedure: At each transect, a total of eight cover measurements are made using a convex spherical densitometer modified as described in Lazorchak *et al*, (1998) where the number of grid points are limited from 96 to 17. While holding the densitometer level at 30 cm above the water surface, one observer counts the number of intersecting points covered by leaves, branches, etc. and records the values (0-17) in the data dictionary, where 0 corresponds to no cover (open sky) and 17 corresponds to total cover. Four readings are taken from the center of the channel facing toward the right bank, upstream, the left bank and downstream. Note that the location of the center of the channel (including dry portions across the transect), is different from the center of the wetted habitat unit. Next, one reading at the right streambank is made facing perpendicular to the stream bank. The procedure is repeated at the left stream bank.

Required Values for data entry: Transect number (1-11), Densiometer direction (Center Up, Down, Right, Left; Right Bank, Left Bank), and Densiometer cover (0-17).

Substrate Size

Purpose: To characterize size of the substrate found within the reach.

Procedure: Eleven pebbles, particles, or pieces of gravel (sediment samples) are measured across the total width of the stream channel at each of 11 transects, for a total of 121 samples recorded for the entire survey.

At each transect, the bankfull width (including any dry portions) is divided into 10, which represents the equal channel width spacing between pebble count samples. The first and last substrate sample across the channel is selected at the stream bank edge at the interface of the bank and bed. If the bankfull width is substantially larger than the distance between bank edges (due to a shallow sloping bank) then the bank edge distance should be measured and divided by 10. The substrate sampling is a modified Wolman (1955) pebble count, which should be referred to by all survey staff. Beginning at the channel edge, the first substrate particle touched in front of the surveyor's boot toe is picked up. By averting eyes and not visually locating particles along the equal intervals of the transect, bias is reduced. It is important to use feel and not sight to select each particle. Using a Vernier caliper or metric ruler, the intermediate b-axis (the dimension by which the particle would pass through a sieve, Figure 1) of the particle is measured and recorded (in millimeters). The actual measurement is recorded, and as part of data transformation, each particle is classified into one of the size classes listed in Table 4. Retaining the actual measurement allows for more accurate calculation of substrate size metrics (i.e., geometric mean or cumulative size distribution thresholds; e.g. D50 (mm)). If the substrate touched is individually too small to pick up, then several particles may be collected for visual inspection. If the substrate is 0.6-2 mm in size and is gritty to the touch, then it is sand and the data value entered is 2 (mm). If the substrate is silty, slimy, or contains organic material that can be broken by hand, then the material is considered silt and the data value entered is 0.06 (mm). All other particles larger than two mm are measured and recorded.

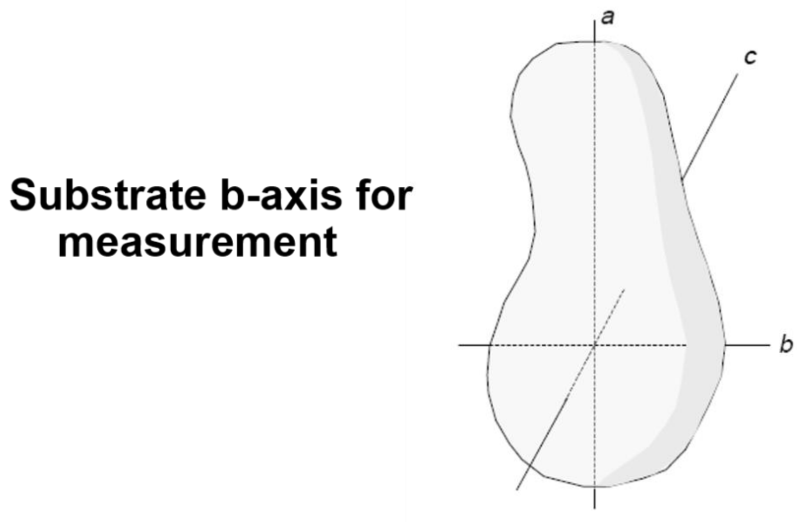

Figure 1. Diagram of substrate axes.

Table 4. Substrate size classes adapted from Lazorchak et al (1998).

Size Class	Size Range (mm)
Fines (silt, organics, smooth or slimy feel)	< 0.06
Sand (feels gritty to the tough)	> 0.06 to 2
Gravel (fine)	> 2 to 16
Gravel (course)	> 16 to 64
Cobble (also size category for Rubble)	> 64 to 250
Boulder (also size category for Riprap)	> 250 to 4000
Hardpan	> 4000
Bedrock (rough)	> 4000
Bedrock (smooth)	> 4000

Required Values for data entry: Transect Number and Substrate Size (11 values).

Riparian Disturbance

Purpose: To characterize the presence of ground disturbance (dominant) near the stream edge in a viewable 5 x 5 meter plot centered on the transect and upland from the edge of the right and left streambanks.

Definitions: Peck et al. (2003) define human disturbances as the following;

"(1) walls, dikes, revetments, riprap, and dams; (2) buildings; (3) pavement/cleared lot (e.g., paved, graveled, dirt parking lot, foundation); (4) roads or railroads, (5) inlet or outlet pipes; (6) landfills or trash (e.g., cans, bottles, trash heaps); (7) parks or maintained lawns; (8) row crops; (9) pastures, rangeland, hay fields, or evidence of livestock; (10) logging; and (11) mining (including gravel mining)."

For the purposes of this survey we group human disturbances into the following categories, as defined:

Clearing: Includes removal of vegetation from over-story, middle story or groundcover for removing timber, creating view corridor, or creating or maintaining cleared lot, parks or maintained lawns, row crops, hay fields, pastures, rangeland, or invasive weed control. This could include excavation.

Trails: Includes cleared pathways where vegetation has been trampled to soil for stream access, general uses, hiking. Trails can be associated with livestock use.

Structure: Includes a building, footing, wall, foundation or extent of riprap/rock at ground level or raised.

Paving: Includes a road grade of any kind whether paved, graveled, railroaded, or used for parking

Other: Typically includes pipes, trash, or other minor use.

None: No current disturbance or human uses is evident. Note that historical logging may have been present within the riparian area that left behind stumps and more recent tree growth.

Procedure: From the transect point that intersects the stream bank, view the edge of the streambank 2.5 meters upstream and 2.5 meters downstream. For this total "belt" width about the transect point, view the riparian area for a distance of 5 meters upland (away from the stream). This plot should be 5 x 5 meter square. Determine if there has been disturbance or influence of the types described above. Choose only the most dominant type of disturbance covering the largest area of the plot or representing the most intense use. Generally the intensity of uses from greater to lesser category levels are Roads, Structures, Clearing, Trails, Other, None.

Required Values for data entry: Transect Number, Streambank (R, L), and Riparian Disturbance Type.

<u>Riparian Invasive Noxious Weed Presence</u>

Purpose: To characterize the presence (dominant) of typical invasive weeds encountered near the stream edge that degrades natural riparian vegetation among 11 transects on the right and left streambanks. Species selected are those that are commonly addressed with/by stewardship activities.

Definitions: For the purposes of this survey we categorize riparian invasive noxious weeds into the following categories for monitoring

Knotweed: Can be one of several regionally known species of invasive knotweeds

Blackberry: Himalayan blackberry is the non-native variety ubiquitously present.

Canary grass: Includes primarily the Reed Canary grass that is ubiquitous in wetlands, along stream corridors, roadside ditches, and stormwater ponds, among other locations.

Vine: This group includes English Ivy and Bittersweet Nightshade.

Other: Can include Scotch Broom, Butterfly Bush, Yellow flag iris, creeping Buttercup.

None: No invasive plants observed in plot.

Procedure: From the transect point that intersects the stream bank, view the edge of the streambank 2.5 meters upstream and 2.5 meters downstream. For this total "belt" width about the transect point, view the riparian area for a distance of 5 meters upland (away from the stream). This plot should be 5 x 5 meter square. Determine if there is any of the plants present. If so choose the most dominant by area or if similar areas are present choose, Knotweed, followed by Vine, then Blackberry, then Canary grass.

Required Values for data entry: Transect Number, Streambank (R, L), and Invasive weed category/type.

Riparian Bank Cover

Purpose: To characterize the dominant cover type along the streambank from the top of bank to the toe of the streambank. Note that this is different from the continuous bank condition survey, which does not characterize types of bank cover, unless there is a modification.

Definitions: The cover refers to the material that is overlying and therefore covering the streambank from the top of the bank (perennial vegetation) to the top of the streambed. Natural material covering the streambank can provide a habitat value at various stream flow stages and may also limit some bank erosion by deflecting or dissipating energy associated with hydraulic shear forces. Categories are as follows;

Brush/Wood: This material is dead or no longer attached to a rooted tree or plant and has either fallen from the streambank or has floated to a resting position that covers the bank.

Artificial: This is material that has been deliberately placed on the streambank, and often is structural (bridge footing) or angular rock.

Bank Vegetation/Live Tree Roots: This material is growing or still attached to rooted plants within or above the streambank and covers the bank and stream in some cases

Boulder/Bedrock: The streambank to a bankfull height may be bedrock or large natural boulders.

None: The streambank is devoid of the other cover types up to the bankfull elevation, often occurring with active streambank erosion.

Procedure: From the transect point that intersects the stream bank, view the edge of the streambank 2.5 meters upstream and 2.5 meters downstream. For this total "belt" width about the transect point, view the riparian area for a distance of 5 meters upland (away from the stream). This plot should be 5 x 5 meter square. Determine if there is bank cover that totals at least 50% of the length of the plot (any cover along 2.5 meters out of 5.0 meters). Bank cover need not cover the height of the bank from top to toe. If not, choose "None." If more than one type of cover category is present choose the one with the most presence.

Required Values for data entry: Transect Number, Streambank (R, L), and Bank cover types.

Streambank Angle

Purpose: To characterize the streambank angle as it may relate to bank instability, integrity, or fish habitat.

Definitions: Streambank angle is described and defined by the slope of the streambank from the edge of the gravel bed of the channel to the top of the streambank. For this survey, there are three streambank angle conditions; Sloping (angled), Vertical, and Undercut. Undercut streambanks have greater value as fish habitat due to the cover and refuge provided, whereas sloping streambanks may reflect less streambank vegetation or integrity and would provide less habitat value at low and higher flow conditions. Sloping streambanks angle away from the center of the channel toward the riparian plot. Vertical streambanks are considered to be within 5 degrees of vertical. Undercut streambanks have an angle that slopes up in the direction of the center of the stream channel.

Procedure: Using a stadia rod, from the center of the stream, position the bottom of the rod at an angle at the edge of the gravel stream bed. Then, rotate the stadia rod on its bottom up toward the streambank. When the rod contacts the top of the streambank, determine if the rod is sloping toward to the center of the channel still, the rod is vertical (or within 5 degrees of vertical), or slopes toward the riparian plot. Enter the bank angle category. Sloping and undercut banks are generally easy to determine from visual assessment.

Required Values for data entry: Transect Number, Streambank (R, L), and Bank angle types.

Channel Gradient

Purpose: To calculate an average reach gradient among sequential transects needed for channel evaluation, secondary metrics and to ground truth GIS derived gradients (see below) used in reach segmentation.

Procedure: Stream gradients are measured in a downstream direction after surveyors complete the transect component of the survey. Stream gradients are measured in a downstream direction between the wetted edges of transects 11 and 10, transects 6 and 5, and transects 2 and 1. Ideally, there should be clear line of sight between flagged transects. If this is not the case and the line of sight is clear between other transects (e.g.; transects 2 and 3), then alternative transect pairs may be used. To do so, one surveyor stands on the upstream transect (11, 6, and 2) and aims a hand level (pea gun) at a stadia rod held vertically by a second surveyor on the downstream transect (10, 5, and 1). The hand level rests on a pre-fabricated rod of known height (approximately eye-level for most staff).

Both rods are placed at the same water depth or at the edge of the wetted channel (the water surface elevation). The vertical elevation between transects is measured and calculated by aiming the level at the survey rod and viewing the value on the rod. The difference is calculated by subtracting the instrument height from the value read off the survey rod. The upstream and downstream transect numbers and their distance apart are known based on the pre-determined transect interval spacing. However, using a laser range-finder, the distance between the rods should be measured for confirmation. This measurement as well as the vertical calculation and transect numbers (for reference) are entered into the data collector. The gradient measurement is repeated two more times at transect pairs as the team moves downstream. The three measurements are averaged to estimate the survey stream gradient.

As part of survey methodological development, measured stream gradients are compared to gradients calculated in a GIS using the corrected stream delineation, the regularly spaced stream transects, and an extraction of LiDAR DEM elevations along the course of the corrected alignment to estimate gradient approximately between the field surveyed transects (1 to 11). The upstream and downstream elevation difference is calculated and divided by the length of the corrected stream line.

Required Values for data entry: Upstream Transect Number (2-11), Downstream Transect Number (1-10), field-measured Horizontal Distance between transects (nearest cm), and calculated Vertical Elevation (nearest mm).

7.5 Continuous Habitat Parameters

For continuous habitat parameters, where survey measurements are made in the main channel, MC is entered in the Channel Type field within the database. SC is entered if survey measurements are made in side channel habitat. All side channel data are organized based on only using the main channel transect where the side channel starts. For example, if one side channel is connected to the mainstem after Transect 1, but before Transect 2, the side channel is named SC 1.1. If a second side channel were to be encountered within the same Transects 1 and 2, it would be named SC 1.2. If follows that one side channel encountered between Transects 3 and 4 would be named SC 3.1, and so on.

Stream Bank Condition

Purpose: To inventory bank modifications and assess bank stability.

Definitions: As follows;

Bank Condition: Banks are categorized as being either “modified” or “natural,” as illustrated below (modified (left) and natural (right), Figure 2).

Figure 2. Photographic examples of modified (left and natural (right) streambanks.

Bank Stability: Banks are stable unless they show indications of any of the following features at or above bankfull stage (Bauer and Burton 1993):

Breakdown - Obvious blocks of bank have broken away and are lying adjacent to the bank breakage.

Slumping or False bank - The bank has obviously slipped down, but cracks may or may not be obvious.

Fracture - A crack is visibly obvious on the bank indicating that the block of bank is about to slump or move into the stream.

Vertical and Eroding- The bank angle is steeper than 80^{o} from the horizontal *and* the bank is mostly uncovered as defined below:

- ≤ 50% of ground cover is perennial vegetation
- ≤ 50% of the bank is covered by roots.
- ≤50% of the bank is protected by rocks of cobble size or larger.
- ≤ 50% of the bank surfaces are protected by wood ≥10-cm in diameter.

Modification Type: Types of bank modification include *Dike/levee, Berm, Revetment, Bulkhead/Structural, Grade, or N/A*. If the type of bank modification is unclear, it is classified as a revetment. *N/A* means there is no modification present and is assigned by default for natural streambanks.

Modification Toe: The toe class is determined by visually examining primary bank material below bankfull stage. Toe classes include *Riprap, Rubble, Structural, and Earth*. Bank material greater than 256 mm (10 in) is considered *Riprap*. Bank material less than 256 mm is considered *Rubble* (Beamer & Henderson, 1998). Other classes such as placed wood, concrete, and gabion are lumped into *Structural* toe class. Unstable, natural banks are assigned a Toe value of *Earth* by default.

Procedure: Stream bank conditions are monitored continuously along both banks. When a section of unstable or modified bank is encountered, the bank feature class in the attribute table is selected, and the right or left bank (facing downstream) is indicated. The data entry and GPS position should be made at the downstream limit of the bank condition. The length of the unstable or modified feature is measured with a rangefinder, the stadia rod or a reel tape. If a side channel is present, the bank condition on the island separating the main channel and side channel is recorded as inner bank.

Required Values for data entry: Location (GPS coordinate of downstream limit), Channel Type (MC/SC), River Bank (Right/Left), Condition (Natural/Modified), Stability (Stable/Unstable), Modification Type (as above), Toe Class (as above), and Length (nearest cm).

Side Channel Habitat

Purpose: To quantify habitat in side channels.

Definitions: Side channels are defined as channels that are separated from the main channel by a stable island and contain the smaller portion of the total flow. A stable island in a forested stream is defined by USFS (1999) as supporting woody vegetation (excluding willow) that is estimated to be at least 5 years old and covers at least 50% of the island surface at or above bankfull elevation. Side channels will have an exposed stream bed. Grassy swales are not considered side channels.

Procedure: Surveyors identify whether or not a potential side channel feature is separated from the main channel by a stable island. If the feature is not separated by a stable island, include it with the main channel measurements, including transects.

Side channel conditions are recorded in the Side Channel feature class in the data dictionary. The side channel outlet is recorded based on transect number and side channel number, as described above, and a GPS point is logged. Side channels are surveyed on the way downstream after the main channel survey is completed. However, the upstream extent or connection of the side channel should be found and flagged in order to return to that location. The side channel features are surveyed following the same method used for continuous survey of mainstem channels, identifying and recording habitat units, unstable banks, and LWD as separate feature classes.

Side channel total length (wet and dry units) and average total width are recorded in the side channel feature class. Total width is estimated based on the average total width of at least two visually representative locations. Total wetted length and mean wetted width are estimated from wetted habitat units within the side channel as part of habitat analysis. Side channels are not included as part of transect cross sections because 1.) side channels can depart far from the mainstem making the transect point difficult to locate, 2.) side channels may be marginal in their characteristics, and, very often, 3.) side channels are dry during summer low flow and are unrepresentative of low flow wetted habitat and dominant discharge processes that transects characterize.

Required Values for data entry: GPS position of downstream outlet to mainstem, Wet Length (nearest 10 cm or calculated later based on sum of wetted habitat unit lengths), Total Length (nearest 10 cm), Wet Width (nearest 10 cm), and Total Width (nearest 10 cm).

Woody Debris

Purpose: To measure the characteristics and quantity of instream wood providing habitat complexity, cover and hydraulic roughness.

Definitions: The minimum size for a qualifying piece of wood is 2.0 meters long and at least 10 cm in diameter along the qualifying length of the piece (WFPB 1997; Fox and Bolton 2007). For pieces that are less than 7.6 m long, the mid-point diameter over the length of the piece is determined for the diameter category. For pieces that are greater than 7.6 m long, the diameter is measured at 7.6 m from the large end. Only downed wood that intercepts the bankfull flow is counted (Figure 3). Wood above bankfull elevation is recorded only if it is part of a jam that contains wood below the bankfull level. Jams are defined as 3 or more touching pieces of wood that are >7.6 m in length and >30 cm in diameter (USFS 1999). Rootwads are defined as having an average diameter of 1 meter or greater.

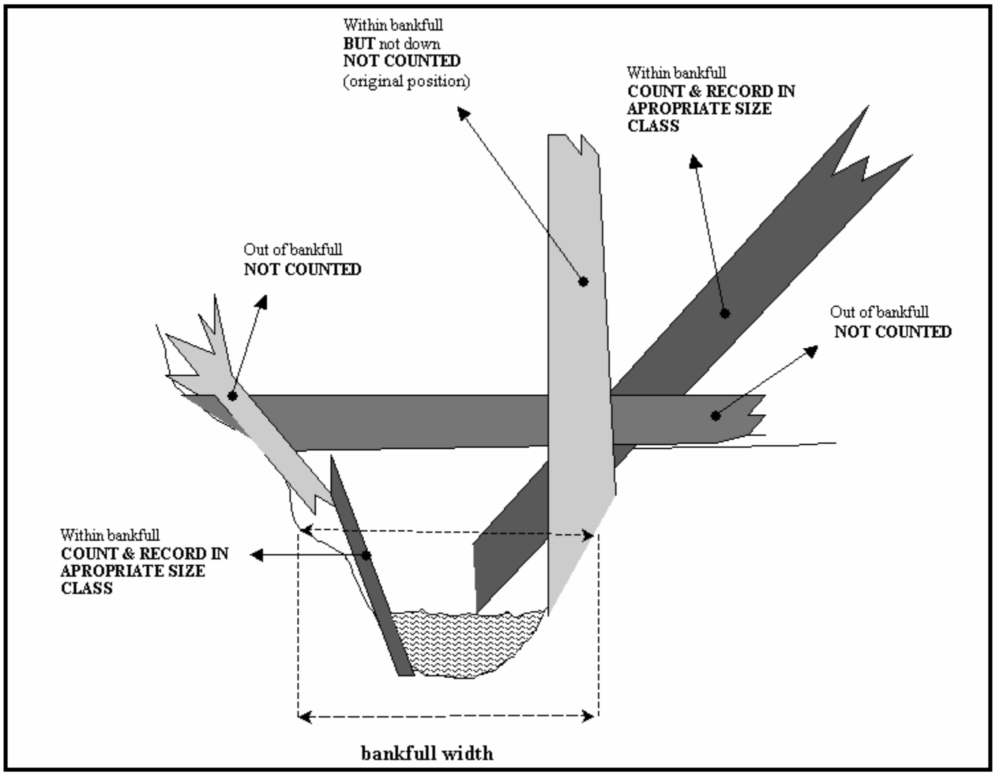

Figure 3. LWD positions in channel.

Trees standing vertically, wholly or partially, within the bankfull area with their weight supported by attached roots are not counted. If this cannot be determined and the stump is creating a qualifying pool, then record the piece as qualifying woody debris.

Procedure: Small wood that is 10-30 cm in diameter and without a qualifying rootwad is tallied and not assigned a location (GPS). Tallies for small wood are entered for the entire reach after the survey. A location (GPS) is recorded for individual pieces of wood 10-30 cm in diameter and that have a qualifying rootwad, as well as all wood that is > 30 cm in diameter. Measure wood with a stadia rod or rangefinder, and bin into diameter and length classes (Table 5). Record whether or not each piece has a qualifying rootwad attached, if it is in contact with low flow (wet), and if it is part of a jam.

Table 5. Woody debris size classes and recording or tally designation for data collection.

	Diameter Class (cm)			
Length Class	**<30**	**30-60**	**60-90**	**>90**
	No Rootwad			
2.0-7.6 m	Tally	Tally	Tally	Tally
	With Rootwad			
2.0-7.6 m	Record	Record	Record	Record
	No Rootwad			
7.6-15 m	Tally	Record	Record	Record
	With Rootwad			
7.6-15 m	Record	Record	Record	Record
	No Rootwad			
>15 m	Tally	Record	Record	Record
	With Rootwad			
>15 m	Record	Record	Record	Record

When a log jam is encountered, the Jam feature class in the data dictionary is utilized. A GPS point is created. Stable jams are surveyed by climbing around and on the jam, as feasible and if safe, to count wood as accurately as possible. Adopt a systematic approach to counting wood within large jams. Wood in jams is surveyed using the same method as single pieces. Each qualifying piece of wood in a jam is assigned a GPS position and noted as being part of a log jam. Small wood (10-30 cm in diameter and without a qualifying rootwad) found in each jam is tallied as in Table 5 and entered into the jam feature class separate from the other non-jam tallies. The amount of wood contained in jams is counted for both inventoried and tallied pieces. Large jams can be inventoried on the way upstream or downstream.

For each log jam, surveyors will use a range finder or stadia rod to estimate the jam length (the leading edge to the downstream edge) and a visually averaged width. This is the average area (footprint) of the log jam. In addition, identify a visually averaged jam height above a base elevation and measure that vertical height. For example, this could be the level of convex gravel bar the jam is resting on, the toe of the streambank the jam is pinned against or another underlying geomorphic streambed feature that has not been altered by the jam. For instance, do not measure the jam height from the base of a scour pool the jam has formed or from a gravel bar deposit at the apex (upstream face) of the jam. The log jam type is categorized as a Bar Apex Jam (BAJ), Bar Top Jam (BTJ), Meander Jam (MJ), or Spanning Jam (SJ). The position in the channel is also determined as one of the following: In the wetted channel, on active gravel bar, on vegetated bar, at edge or apex of forested island. If a jam spans different channel positions, the most active part of the channel should be selected.

Required Values for data entry: Channel Type, Length Class, Diameter Class, Rootwad

(Yes/No), Wet (Yes/No), Part of a Jam (Yes/No), Jam type (BAJ, BTJ, MJ), Jam position (in-channel, active bar, vegetated bar, forested island), Jam length (nearest 10 cm), Jam width (nearest 10 cm), Jam height (nearest 10 cm), and Jam pool (yes/no). Add final tallies for main channel and side channel wood under Reach Info.

Pool Habitat

Purpose: To measure slow water habitat area available for holding and rearing.

Definitions: As follows;

Pool: A pool is a section of stream channel where water is impounded within a closed topographical depression (Abbe and Montgomery, 1996).

Pool Type: Primary pools are located in line with the thalweg while Backwater pools are separated from the main flow (Lazorchak et al., 1998).

Pool Forming Factor: The feature or process that leads to the formation of a pool is described by one of the following;

Rip Rap or Modification – formed by scour along a hardened bank or other instream modification; such as bridge pier or structural bulkhead

Bedrock – formed by scour along bedrock material (includes compact till that is laterally resistant to erosion)

Wood – formed by scour around naturally occurring or placed wood or by being impounded by wood (a dammed pool) or plunging over wood.

Beaver – formed behind beaver dam or scoured from other beaver activity

Free Form – formed in ways other than above, such as from flow convergence or lateral bank resistance.

Boulder – formed by scour around naturally occurring or placed boulder large enough to create required residual depth.

Pool Wetted Area – Wetted area is defined as the total pool length multiplied by the average wetted width, measured from several locations.

Procedure: For a habitat unit to qualify as a pool in this survey, it must meet the minimum wetted area and depth requirements in Table 6, consistent with Pleus et al 1999.

Table 6. Minimum pool size requirements.

Bank Full Width (m)	Wetted Area (m^2)	Residual Pool Depth (m)
0 – 2.49	0.5	0.10
2.5 – 4.9	1.0	0.20
5.0 – 9.9	2.0	0.25
10.0 – 14.9	3.0	0.30
15.0 – 19.9	4.0	0.35
>20	5.0	0.40

When a potential pool is encountered, the tailout depth and maximum depth are measured using a stadia rod in order to calculate the residual pool depth (maximum depth - tailout depth). If the residual depth is greater than the minimum required for the established bankfull width, the mean wetted width and wetted length of the pool are measured. If the wetted area (length * width) does not meet the requirements in Table 6, the habitat area is not recorded as a pool. In this case, the habitat unit area is lumped with an adjacent unit or recorded separately as an "other" habitat (predominantly glide- or run-like habitat).

When two or more pools occur in sequence they are measured separately whenever there is a clear division (tailout) between them, when they have separate pool forming factors, or when they differ in pool type. Also, when the end of the survey (transect 11) falls within a pool, the maximum depth of that pool is recorded even if that point is outside the survey reach. However, only the wetted and functional areas that lie within the survey reach are measured and recorded.

Required Values for data entry: Channel Type, Pool Type, Pool Form Factor, Tailout Depth, Maximum Depth, Wetted Width, and Wetted Length.

Riffle Habitat

Purpose: To assess total wetted habitat area and composition among habitat unit types.

Definitions: A riffle is a section of stream with shallow, turbulent, higher velocity flow. The water surface may be generally unbroken, rippled, or have small waves. Riffles are distinguished from slightly deeper, slower moving sections with a smooth surface that are considered "other" (i.e., glide). The wetted width boundary of riffles is the point at which substrate particles are no longer surrounded by free water (Lazorchak *et al.*, 1998)

Procedure: The most downstream point of the riffle is used to record a GPS position and access the attribute table for data entry. The average wetted width and wetted length are measured with rangefinder or reel tape to determine the most accurate representation of riffle area. The riffle type is selected based on the dominant substrate size (gravel, small cobble, large cobble, or boulder) present. The maximum depth of the riffle is recorded.

Required Values: Channel Type, Dominant Substrate Type, Wetted Width, Wetted Length, and Maximum Depth.

Other Habitat

Purpose: To quantify other habitat areas as part of calculating total wetted area and composition among habitat unit types.

Definitions: A section of stream that is not a pool and not a riffle will generally demonstrate uniform cross-sectional flow, and unbroken surface (not turbulent) and mostly homogeneous depth along the thalweg. Flow may be fast but is usually slower than riffles. These are typically referred to as glides or runs and usually lack bed deforming obstructions, but may contain sizable boulders. For the purposes of this protocol these habitat units are labeled "*Other*."

Procedure: The most downstream point of the other habitat unit type is used to record a GPS position and access the attribute table for data entry. The average wetted width and wetted length are measured to determine the most accurate representation of the area. The dominant substrate size is characterized, as is the maximum depth.

Required Values: Channel Type, Dominant Substrate Type, Wetted Width, Wetted Length, and Maximum Depth.

8.0 Data Management

8.1 Tablet Computing and File Management

Survey data are entered into GPS-enabled tablet computers operating on the Snohomish County wireless data service provider network. Data are entered into ArcCollector and stored with their specific attributes (Appendix A) and geospatial location. If spatial position is not available due to poor satellite reception, in the worst case scenario, the survey data position can be digitized in the field over recent ortho-photos and stored as background files in the field computer. With network connectivity, all data collected are immediately synched through the cloud to ArcGIS online. If data are collected offline (outside of network connectivity), they are stored on the tablet computer until they can be manually synched to the cloud.

Once data have been collected and synched to the cloud, they are accessible through ArcGIS online (AGOL). Survey team members with AGOL licenses are able to access and view data through AGOL as well as download the data as database files (.dbf) or shapefiles (.shp) for offline viewing and editing in ArcMap. Data are backed up through the field season by downloading all the available completed survey data to an office PC. Once all the surveys have been completed, all the data are downloaded from AGOL to an office computer. All data are reviewed for errors on ArcMap, and any changes to the data are documented. Any potential recording errors are noted and communicated to the data manager.

9.0 Records Management

All stream data are tagged with unique reach identifiers and stored in folders on the Snohomish County network under the State of the Waters folder system: These data can be opened, edited, and analyzed using ArcMap or Microsoft Excel.

In the future, these data will be uploaded to a relational database called WISKI for further analysis with site specific water quality and hydrology data.

10.0 Safety Requirements

10.1 Apparel and Equipment

Staff are provided appropriate Personal Protection Equipment (PPE) to minimize hazards. Teams of two should be considered especially for sites where samples are collected on larger streams/rivers or access is long distance from the vehicle or over difficult terrain.

10.2 Training Requirements

Washington State Department of Labor and Industries requires that employers provide a safe work environment through communicating hazards and providing adequate training. Required safety training, inclusive of General Field Safety and Swiftwater Rescue and awareness have been identified by position. Additional requirements include: Defensive Driving, First Aid, and CPR/AED training.

11.0 Invasive Species and Decontamination Procedures

Special care must be taken to prevent the spread of aquatic invasive species (AIS). Two problem species have been tentatively or definitively identified in western Washington watersheds. These include *Didymosphenia geminata* (Didymo) and New Zealand Mud Snail (*Potamopyrgus anitpodarum*).

Washington Department of Ecology currently identify problem invasive species by two categories: Areas of Extreme Concern and Areas of Moderate Concern. Watersheds with New Zealand Mud Snails are Areas of Extreme Concern. Staff must follow standard operating procedures as adapted from (Parsons et al., 2012) to ensure sampling in areas where the New Zealand Mudsnail exists do not unintentionally promote distribution into other waterbodies.

Any sampling planned in watersheds of Lake Washington should be followed by decontamination procedures for Areas of Extreme Concern.

- Habitat assessment involves contacting stream water or wet streamside soils during sample collection so should be subjected to decontamination procedures using chemicals or heat, especially when cold treatment (4 hrs. at -40^{o}C) or drying (48 hours to fully dry) cannot be completed in time.
- Wearing short rubber boots will simplify decontamination, while wearing felt-soled boots will make decontamination more difficult. Check regulations from Washington Department of Fish and Wildlife to ensure felt-bottomed soles are legal for use in specific waterbodies.

New Zealand Mud Snails

New Zealand Mud Snails have been found in numerous areas of Washington State, where they can potentially cause tremendous environmental and economic impacts. These areas are now considered to be of Extreme Concern. In western Washington they include Marathon Park, Capital Lake (Olympia), and Kelsey and Thornton Creeks in the Seattle area, and Union Slough in the lower Snohomish River.

Review Appendix B in the Quality Assurance Monitoring Plan for State of Our Waters Monitoring for detailed decontamination instructions for equipment that may contact waters known to contain aquatic invasive species (Snohomish County 2019).

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Appendix A

Snohomish County 2018 Wadeable Stream Survey Data Dictionary for State of Waters Monitoring Program (For ESRI Collector for ArcGIS or Trimble Pathfinder Office Pro for Geoexplorer XH/XT)

```
"Wadeable_MAM", Dictionary
"Reach_Info", point, "", None, 1, Code
  "Reach_ID", text, 30, normal, normal, Label2
  "Surveyor_1", menu, normal, normal
  "Surveyor_2", menu, normal, normal
  "Surveyor_3", menu, normal, normal
  "Wd_Tally_MC", numeric, 0, 0, 10000, 0, normal, "Small wood tally main channel", normal
  "Wd_Tally_SC", numeric, 0, 0, 10000, 0, normal, "Small wood tally main channel", normal
  "Comment_1", text, 30, normal, normal, Label1
  "Comment_2", text, 30, normal, normal

"Transect", point, "", 1, seconds, 1, Code
  "Transect", numeric, 1, 1.0, 11.0, 1.0, normal, normal, Label1
  "Wet_Width", numeric, 1, 0.0, 1000.0, 0.0, normal, normal
  "BFW", numeric, 1, 0.0, 1000.0, 0.0, normal, normal
  "BFD", numeric, 2, 0.00, 10.00, 0.00, normal, normal
  "HabUnit_Type", menu, normal, normal
    "Pool",[P]
    "Riffle",[R]
    "Other",[O]
  "Canopy_R", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_U", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_L", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_D", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_RB", numeric, 0, 0, 17, 0, normal, normal
  "Canopy_LB", numeric, 0, 0, 17, 0, normal, normal
  "Substr1_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal, Label2
  "Substr2_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr3_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr4_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr5_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr6_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr7_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr8_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr9_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr10_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "Substr11_Meas", numeric, 2, 0.01, 4000.00, 0.01, normal, normal
  "RB_Angle", menu, normal, normal, Label2
    "Angled",[O],
    "Undercut",[O],
    "Vertical",[O],
  "LB_Angle", menu, normal, normal, Label2
    "Angled",[O],
    "Undercut",[O],
    "Vertical",[O],
  "RB_Disturbance", menu, normal, normal
```

```
      "Clearing",
      "Trails",
      "None",
      "Structure/Paving",
      "Other"
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      "Clearing",
      "Trails",
      "None",
      "Structure/Paving",
      "Other"
   "RB_CoverType", menu, normal, normal
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      "Brush/Wood",
      "Artificial",
      "Bank Vegetation/Live Tree Roots",
      "Boulder/Bedrock"
   "LB_CoverType", menu, normal, normal
      "None",
      "Brush/Wood",
      "Artificial",
      "Bank Vegetation/Live Tree Roots",
      "Boulder/Bedrock"
   "RB_Invasives", menu, normal, normal
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      "Knotweed",
      "Blackberry",
      "Vine/Ivy",
      "Canarygrass"
      "Other"
   "LB_Invasives", menu, normal, normal
      "None",
      "Knotweed",
      "Blackberry",
      "Vine/Ivy",
      "Canarygrass"
      "Other"
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"Wood", point, "", None, 1, Code
   "Channel_Type", menu, normal, normal
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      "Side Channel",[SC]
   "Length_Class", menu, normal, normal, Label1
      "2.0m - 7.6m",[3]
      "7.6m - 15m",[1]
      "> 15m",[2]
   "Diam_Class", menu, normal, normal
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      "30 - 60 cm",[1]
      "60 - 90 cm",[2]
      "> 90 cm",[3]
```

```
  "Rootwad", menu, normal, normal
    "Yes",[Y]
    "No",[N]
  "Wet", menu, normal, normal
    "Yes",[Y]
    "No",[N]
  "Part_Jam", menu, normal, normal
    "Yes",[Y]
    "No",[N], default
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  "Comment_1", text, 30, normal, normal, Label1

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    "Side Channel",[SC]
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  "Jam_Height", numeric, 2, 0.00, 10.00, 0.00, normal, normal, Label1
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    "No",[N], default
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    "Main Channel",[MC], default
    "Side Channel",[SC]
  "Pool_Type", menu, required, "Choose Pool Type", normal
    "Primary",[P]
    "Backwater",[B]
  "Pool_Form", menu, required, "Choose Pool Forming Factor", normal
    "Free form",[FF]
    "Rip rap",[RR]
    "Bed rock",[BR]
    "Wood",[WD]
    "Beaver",[BV]
    "Boulder",[BO]
  "Max_Depth", numeric, 2, 0.00, 10.00, 0.00, normal, normal, Label1
  "Tail_Depth", numeric, 2, 0.00, 10.00, 0.00, normal, normal, Label2
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  "Wet_Length", numeric, 1, 0.0, 3000.0, 0.0, normal, normal
  "Pool_Substrate", menu, normal, normal
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    "Boulder",[BO]
    "Large_Cobble",[LC]
    "Small_Cobble",[SC]
    "Large Gravel",[LG]
    "Small Gravel",[SG]
    "Sand",[SA]
```

```
    "Silt",[SI]
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    "Brush/Wood",
    "Artificial",
    "Boulder/Bedrock",
    "Bank Vegetation/Live Tree Roots"
  "Comment_1", text, 30, normal, normal, Label1

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  "Channel_Type", menu, normal, normal
    "Main Channel",[MC], default
    "Side Channel",[SC]
  "Riffle_Substrate", menu, normal, normal
    "Bedrock",[BD]
    "Boulder",[BO]
    "Large_Cobble",[LC]
    "Small_Cobble",[SC]
    "Large Gravel",[LG]
    "Small Gravel",[SG]
    "Sand",[SA]
    "Silt",[SI]
  "Wet_Width", numeric, 1, 0.0, 1000.0, 0.0, normal, normal, Label1
  "Wet_Length", numeric, 1, 0.0, 1000.0, 0.0, normal, normal
  "Max_Depth", numeric, 2, 0.00, 10.00, 0.00, normal, normal, Label1
  "Comment_1", text, 30, normal, normal, Label1

"Other", point, "", None, 1, Code
  "Channel_Type", menu, normal, normal
    "Main Channel",[MC], default
    "Side Channel",[SC]
   "Other_Substrate", menu, normal, normal
    "Bedrock",[BD]
    "Boulder",[BO]
    "Large_Cobble",[LC]
    "Small_Cobble",[SC]
    "Large Gravel",[LG]
    "Small Gravel",[SG]
    "Sand",[SA]
    "Silt",[SI]
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  "Wet_Length", numeric, 1, 0.0, 1000.0, 0.0, normal, normal
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  "Comment_1", text, 30, normal, normal, Label1

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    "Main Channel",[MC], default
    "Side Channel",[SC]
  "RIVER_BANK", menu, required, required
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```
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    "Left",[Left]
  "LOCATION", menu, normal, normal, Label2
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    "Inner Bank",[I]
  "CONDITION", menu, normal, normal
    "Natural",[N]
    "Modified",[M]
  "STABILITY", menu, normal, normal
    "Stable",[S]
    "Unstable",[U]
  "HMOD_TYPE", menu, normal, "Enter N/A for Natural, Set Back", normal
    "Dike/Levee",[DI]
    "Berm",[BE]
    "Revetment",[RE]
    "Bulkhead",[BU]
    "Grade",[GR]
    "N/A",[NA], default
  "HMOD_TOE", menu, normal, "Describe bank material at bankfull toe", normal
    "Rip Rap (GT 256 mm) ",[RI]
    "Rubble (LT 256 mm)",[RU]
    "Structural",[ST]
    "LWD",[WD]
    "Earth/Natural",[EA], default
  "Bnk_Length", numeric, 1, 1.0, 10000.0, 1.0, normal, normal, Label1
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"Side_Chan", point, "", 1, seconds, 1, Code
  "Transect_ID", numeric, 1, 0.0, 10000.0, 0.0, normal, normal
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  "Wet_Width", numeric, 1, 0.0, 2000.0, 0.0, normal, normal
  "Total_Width", numeric, 1, 0.0, 2000.0, 0.0, normal, normal
  "Comment_1", text, 30, normal, normal, Label1

"Gradient", point, "", None, 1, Code
  "UpStm_tran", numeric, 0, 0, 12, 0, normal, normal, Label2
  "DnStm_tran", numeric, 0, 0, 12, 0, normal, normal
  "Vertical Difference", numeric, 2, 0.00, 100.00, 0.00, normal, normal, Label1
  "MEASURE", numeric, 0, 0, 10, 1, normal, "Adds an identifier to each gradient", normal, 1
  "Comment_1", text, 30, normal, normal, Label1
```

Appendix B

Frequently Cited Habitat Indicator Suitability Criteria

Indicator	Criteria	Metric	Source
Woody Debris (LWD)	80 Pieces (≥15m length and ≥ 0.6m diameter) 2 Pieces (≥ 2m length and ≥0.1m diameter) **Key Pieces** >0.3 (0 -10m BFW) >0.5 (10 - 20m BFW) **Woody Debris Volume** >99 m³ / 100m CL (<30mBFW) >317 m³ / 100m CL (>30mBFW) Predicted mean LWD pieces/CW	Frequency (pieces/mile) Frequency (pieces/channel width) Frequency (pieces/channel width) Volume (m³/ 100m of channel length) $Y=0.22x^{1.26}$	NMFS (1996) WFPB (1997) WFPB (1997) Fox and Bolton (2007)
Pool	Channel width - # pools/mile 1.5m - 164 3m - 96 4.5m - 70 6m - 56 7.6m - 47 15m - 26 23m - 23 30.5m - 18 <2 channel widths per pool Percent pool > 55% Sufficient deep pools >1m deep with good cover and cool water	Frequency (pools/Mile) Frequency (channel width/pool) Percent (% pool) Count (pool)	NMFS (1996) WFPB (1997) WFPB (1997) NMFS (1996) WFPB (1997)
Substrate	Sand is never dominant or subdominant Fines < 0.85 mm in spawning gravel are <12% good (12-17% fair, >17% poor)	Ranking (substrate size class) Percent composition	WFPB (1997) NMFS (1996)
Stream-bank condition	> 90% Stable, <10% actively eroding banks >95% unarmored	Percent (% stable or % eroding banks Percent (natural banks)	NMFS (1996) NOAA (2003)
Off – Channel	Off-channel areas are frequently hydrologically linked to main channel; over bank flows occur and maintain wetland functions, riparian vegetation and succession.	No metric	NMFS (1996)
Cover	Suitable cover ≥90% for bank cover; suitable center-channel cover for shading varies as a function of BFW dimension; 90-50% for increasing elevation (to 2000ft)	Percent cover or percent view-to- sky	WFPB (1997) Ecology (2007)

Appendix C

CHEAT SHEETS FOR FIELD WORK

Snohomish County Wadeable Stream Survey Transect (1/2 transect) Intervals Cheat Sheet (cut and laminate).

Bank Full Width (m)	Reach Length (m)	Trans 1	Trans 1.5	Trans 2	Trans 2.5	Trans 3	Trans 3.5	Trans 4	Trans 4.5	Trans 5	Trans 5.5	Trans 6	Trans 6.5	Trans 7	Trans 7.5	Trans 8	Trans 8.5	Trans 9	Trans 9.5	Trans 10	Trans 10.5	Trans 11
0 - 2.5	50	0	2.5	5	7.5	10	13	15	18	20	23	25	28	30	33	35	38	40	43	45	48	50
2.5 - 4.9	100	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
5.0 - 9.9	200	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
10.0 - 14.9	300	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300
15.0 - 19.9	400	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
20 - 30	600	0	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540	570	600
>30	800	0	40	80	120	160	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800

Bank Condition Characterization

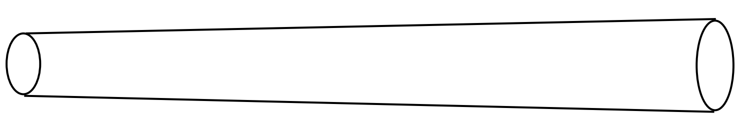
Stream Bank	Condition	Stability	Mod Type	Mod Toe
L	Modified	Stable	Dike/levy/berm	Rip Rap
R		Unstable	Revetment	Rubble
			Bulkhead	Structural
			Grade	Earth/Natural
	Natural	Unstable	N/A - None	Earth/Natural

Minimum Pool Area and Depth Requirements

Bank Full Width (m)	Area (m^2)	Residual Pool Depth (m)
0 – 2.49	0.5	0.10
2.5 – 4.9	1.0	0.20
5.0 – 9.9	2.0	0.25
10.0 – 14.9	3.0	0.30
15.0 – 19.9	4.0	0.35
>20	5.0	0.40

Wood Characterization – must be ≥2 meters in length and ≥10 cm in diameter at narrowest/tapered end

10cm



Diameter Class	Length Class	Rootwad	Wet	Part of Jam
< 30 cm	2.0 -7.6 m	Y	Y	Y
30 - 60 cm	7.6 -15 m	N	N	N
60 - 90 cm	> 15 m			
> 90 cm				

If both <30cm and no rootwad are true, then tally piece. Otherwise record using data dictionary.

Wood Counts

1. Inventory individual larger pieces in iPad – Wood shapefile.
2. Count small individual pieces with manual tally counter - “clicker” enter final total in Site_info shapefile
3. For wood in Jams, add pieces to iPad - Wood shapefile - AND assign Jam ID number as Transect number + jam number. For example if 2 Jams occur between transects 5 and 6, the Jam stations are 5.1 and 5.2 respectively. Station number IS REQUIRED for each piece in jam.
4. Separately count all small pieces in individual jams with 2nd “clicker” – enter tally in Jam shapefile.
5. Total Wood for Survey is iPad inventory (individual & jam) + jam tally + survey tally.

Substrate size classes adapted from Lazorchak *et al*, (1998).

Size Class	Size Range (mm)
Fines/Silt	< 0.06
Sand	> 0.06 to 2
Gravel (fine)	> 2 to 16
Gravel (course)	> 16 to 64
Cobble	> 64 to 250
Boulder	> 250 to 4000
Hardpan	> 4000
Bedrock (rough)	> 4000
Bedrock (smooth)	> 4000

Discharge intervals across wetted portion of stream channel for flow measurement.

Feet	Meters	Number of stations
< 1.6	< 0.5	5 to 6
> 1.6 and < 3.3	> 0.5 and < 1	6 to 7
> 3.3 and < 9.8	> 1 and < 3	7 to 12
> 9.8 and < 16.4	> 3 and < 5	13 to 16
> 16.4	≥ 5	≥ 22

Appendix D

Estimate of wood volume by length and diameter classes using formula in Watershed Analysis (WFBP 1997)

Wood Inventory Categories	Mid-Point Length x Diameter	Formula Length * π * $(Diam/2)^2$	Volume (cm^3)	Volume (m^3)*	Volume m^3 with multiplier %
"Clicker" (10-30 cm >2.0m <u>no</u> rootwad)	4.8m x 20cm	480 x 3.14 x 10^2	150720.00	0.15	for rootwad
2.0-7.6m x 10-30cm w/rootwad	4.8m x 20cm	480 x 3.14 x 10^2	150720.00	0.15	0.24
7.6-15m x 10-30cm w/rootwad	11.3m x 20cm	1130 x 3.14 x 10^2	354820.00	0.35	0.46
>15m x 10-30cm w/rootwad	15m x 20cm	1500 x 3.14 x 10^2	471000.00	0.47	0.52
2.0-7.6m x 30-60cm	4.8m x 45cm	480 x 3.14 x 22.5^2	763020.00	0.76	1.22
7.6-15m x 30-60cm	11.3m x 45cm	1130 x 3.14 x 22.5^2	1796276.25	1.80	2.34
>15m x 30-60cm	15m x 45cm	1500 x 3.14 x 22.5^2	2384437.50	2.38	2.62
2.0-7.6m x 60-90cm	4.8m x 75cm	480 x 3.14 x 37.5^2	2119500.00	2.12	3.39
7.6-15m x 60-90cm	11.3m x 75cm	1130 x 3.14 x 37.5^2	4989656.25	4.99	6.49
>15m x 60-90cm	15m x 75cm	1500 x 3.14 x 37.5^2	6623437.50	6.62	7.29
2.0-7.6m x >90cm	4.8m x 90cm	480 x 3.14 x 45^2	3052080.00	3.05	4.88
7.6-15m x >90cm	11.3m x 90cm	1130 x 3.14 x 45^2	7185105.00	7.19	9.34
>15m x > 90cm	15m x 90cm	1500 x 3.14 x 45^2	9537750.00	9.54	10.49
In excel, enter length (m)/width (diam cm)	<u>*15*</u>	<u>*90*</u>	<u>*9537750.00*</u>	<u>*9.54*</u>	<u>*12.40*</u>

Estimated volume increase for Rootwad by length class; scales with increasing diameter (no reference).	2.0-7.6 m	60%
	7.6-15.0	30%
	>15 m	10%

* rootwad is not included in volume calculation and only used to qualify wood as LWD to be categorized in to volume class

Appendix E

Table of wood volume calculations based on length (nearest 1 m) and diameter (nearest 5 cm) from Watershed Analysis (WFPB 1997). Estimates of additional wood volume from attached rootwads are not included.

Estimated Wood Volumes for a Given Length and Diameter

(Volume in m^3)

Length (m)	Diameter (m)																												
	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50
1	0.01	0.02	0.03	0.05	0.07	0.10	0.13	0.16	0.20	0.24	0.28	0.33	0.39	0.44	0.50	0.57	0.64	0.71	0.79	0.87	0.95	1.04	1.13	1.23	1.33	1.43	1.54	1.65	1.77
2	0.02	0.04	0.06	0.10	0.14	0.19	0.25	0.32	0.39	0.48	0.57	0.66	0.77	0.88	1.01	1.13	1.27	1.42	1.57	1.73	1.90	2.08	2.26	2.45	2.65	2.86	3.08	3.30	3.53
3	0.02	0.05	0.09	0.15	0.21	0.29	0.38	0.48	0.59	0.71	0.85	1.00	1.16	1.33	1.51	1.70	1.91	2.13	2.36	2.60	2.85	3.12	3.39	3.68	3.98	4.29	4.62	4.95	5.30
4	0.03	0.07	0.13	0.20	0.28	0.38	0.50	0.64	0.78	0.95	1.13	1.33	1.54	1.77	2.01	2.27	2.54	2.84	3.14	3.46	3.80	4.16	4.52	4.91	5.31	5.72	6.16	6.60	7.07
5	0.04	0.09	0.16	0.25	0.35	0.48	0.63	0.80	0.98	1.19	1.42	1.66	1.93	2.21	2.52	2.84	3.18	3.55	3.93	4.33	4.75	5.20	5.66	6.14	6.64	7.16	7.70	8.26	8.84
6	0.05	0.11	0.19	0.29	0.42	0.58	0.75	0.95	1.18	1.43	1.70	1.99	2.31	2.65	3.02	3.40	3.82	4.25	4.71	5.20	5.70	6.23	6.79	7.36	7.96	8.59	9.23	9.91	10.60
7	0.05	0.12	0.22	0.34	0.49	0.67	0.88	1.11	1.37	1.66	1.98	2.32	2.70	3.09	3.52	3.97	4.45	4.96	5.50	6.06	6.65	7.27	7.92	8.59	9.29	10.02	10.77	11.56	12.37
8	0.06	0.14	0.25	0.39	0.56	0.77	1.01	1.27	1.57	1.90	2.26	2.66	3.08	3.54	4.02	4.54	5.09	5.67	6.28	6.93	7.60	8.31	9.05	9.82	10.62	11.45	12.31	13.21	14.14
9	0.07	0.16	0.28	0.44	0.63	0.87	1.13	1.43	1.76	2.14	2.55	2.99	3.47	3.98	4.53	5.10	5.72	6.38	7.07	7.79	8.55	9.35	10.18	11.04	11.94	12.88	13.85	14.86	15.90
10	0.08	0.18	0.31	0.49	0.70	0.96	1.26	1.59	1.96	2.38	2.83	3.32	3.85	4.42	5.03	5.67	6.36	7.09	7.85	8.66	9.50	10.39	11.31	12.27	13.27	14.31	15.39	16.51	17.67
11	0.09	0.19	0.35	0.54	0.77	1.06	1.38	1.75	2.16	2.61	3.11	3.65	4.24	4.86	5.53	6.24	7.00	7.80	8.64	9.53	10.45	11.43	12.44	13.50	14.60	15.74	16.93	18.16	19.44
12	0.09	0.21	0.38	0.59	0.84	1.15	1.51	1.91	2.35	2.85	3.40	3.99	4.62	5.30	6.04	6.80	7.63	8.51	9.42	10.39	11.40	12.47	13.57	14.72	15.92	17.17	18.47	19.81	21.20
13	0.10	0.23	0.41	0.64	0.91	1.25	1.63	2.07	2.55	3.09	3.68	4.32	5.01	5.75	6.54	7.37	8.27	9.22	10.21	11.26	12.35	13.51	14.70	15.95	17.25	18.60	20.01	21.46	22.97
14	0.11	0.25	0.44	0.69	0.98	1.35	1.76	2.23	2.74	3.33	3.96	4.65	5.39	6.19	7.04	7.94	8.90	9.93	10.99	12.12	13.30	14.55	15.83	17.18	18.58	20.03	21.55	23.11	24.74
15	0.12	0.27	0.47	0.74	1.05	1.44	1.88	2.39	2.94	3.56	4.25	4.98	5.78	6.63	7.55	8.51	9.54	10.64	11.78	12.99	14.25	15.59	16.97	18.41	19.91	21.47	23.09	24.77	26.51
16	0.13	0.28	0.50	0.79	1.12	1.54	2.01	2.54	3.14	3.80	4.53	5.31	6.16	7.07	8.05	9.07	10.18	11.34	12.56	13.86	15.20	16.62	18.10	19.63	21.23	22.90	24.62	26.42	28.27
17	0.13	0.30	0.53	0.83	1.19	1.64	2.14	2.70	3.33	4.04	4.81	5.64	6.55	7.51	8.55	9.64	10.81	12.05	13.35	14.72	16.15	17.66	19.23	20.86	22.56	24.33	26.16	28.07	30.04
18	0.14	0.32	0.57	0.88	1.26	1.73	2.26	2.86	3.53	4.28	5.09	5.98	6.93	7.96	9.05	10.21	11.45	12.76	14.13	15.59	17.10	18.70	20.36	22.09	23.89	25.76	27.70	29.72	31.81
19	0.15	0.34	0.60	0.93	1.33	1.83	2.39	3.02	3.72	4.51	5.38	6.31	7.32	8.40	9.56	10.77	12.08	13.47	14.92	16.45	18.05	19.74	21.49	23.31	25.21	27.19	29.24	31.37	33.57
20	0.16	0.35	0.63	0.98	1.40	1.92	2.51	3.18	3.92	4.75	5.66	6.64	7.70	8.84	10.06	11.34	12.72	14.18	15.70	17.32	19.00	20.78	22.62	24.54	26.54	28.62	30.78	33.02	35.34
21	0.16	0.37	0.66	1.03	1.47	2.02	2.64	3.34	4.12	4.99	5.94	6.97	8.09	9.28	10.56	11.91	13.36	14.89	16.49	18.19	19.96	21.82	23.75	25.77	27.87	30.05	32.32	34.67	37.11
22	0.17	0.39	0.69	1.08	1.54	2.12	2.76	3.50	4.31	5.23	6.23	7.30	8.47	9.72	11.07	12.47	13.99	15.60	17.27	19.05	20.90	22.86	24.88	26.99	29.19	31.48	33.86	36.32	38.87
23	0.18	0.41	0.72	1.13	1.61	2.21	2.89	3.66	4.51	5.46	6.51	7.64	8.86	10.17	11.57	13.04	14.63	16.31	18.06	19.92	21.85	23.90	26.01	28.22	30.52	32.91	35.40	37.97	40.64
24	0.19	0.42	0.75	1.18	1.68	2.31	3.02	3.82	4.70	5.70	6.79	7.97	9.24	10.61	12.07	13.61	15.26	17.02	18.84	20.76	22.80	24.94	27.14	29.45	31.85	34.34	36.94	39.62	42.41
25	0.20	0.44	0.79	1.23	1.75	2.41	3.14	3.98	4.90	5.94	7.06	8.30	9.63	11.05	12.58	14.18	15.90	17.73	19.63	21.65	23.75	25.98	28.28	30.68	33.18	35.78	38.48	41.28	44.18
26	0.20	0.46	0.82	1.28	1.82	2.50	3.27	4.13	5.10	6.18	7.36	8.63	10.01	11.49	13.08	14.74	16.54	18.43	20.41	22.52	24.70	27.01	29.41	31.90	34.50	37.21	40.01	42.93	45.94
27	0.21	0.48	0.85	1.33	1.89	2.60	3.39	4.29	5.29	6.42	7.64	8.96	10.40	11.93	13.58	15.31	17.17	19.14	21.20	23.38	25.65	28.05	30.54	33.13	35.83	38.64	41.55	44.58	47.71
28	0.22	0.49	0.88	1.37	1.96	2.69	3.52	4.45	5.49	6.65	7.92	9.30	10.78	12.38	14.08	15.88	17.81	19.85	21.98	24.25	26.60	29.09	31.67	34.36	37.16	40.07	43.09	46.23	49.46
29	0.23	0.51	0.91	1.42	2.03	2.79	3.64	4.61	5.68	6.89	8.21	9.63	11.17	12.82	14.59	16.44	18.44	20.56	22.77	25.11	27.55	30.13	32.80	35.58	38.48	41.50	44.63	47.88	51.24
30	0.24	0.53	0.94	1.47	2.10	2.89	3.77	4.77	5.88	7.13	8.49	9.96	11.55	13.26	15.09	17.01	19.08	21.27	23.55	25.98	28.50	31.17	33.93	36.81	39.81	42.93	46.17	49.53	53.01

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